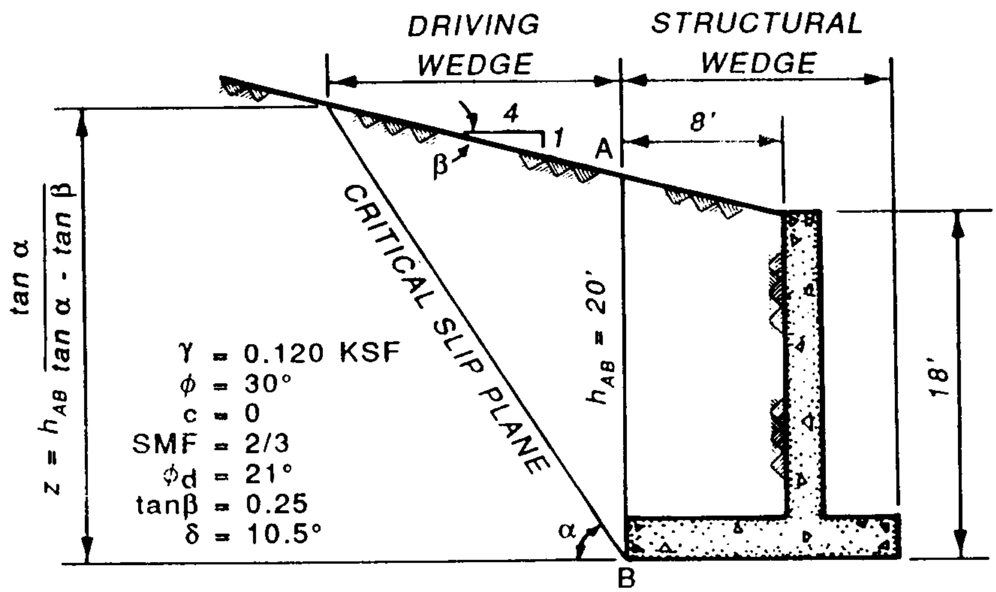
EXAMPLES OF EARTH PRESSURE COMPUTATIONS USING SIMPLIFIED PRESSURE COEFFICIENT METHOD INCLUDING THE EFFECTS OF WALL FRICTION

1. The following examples demonstrate the method of computing earth pressures using the simplified pressure coefficient method described in paragraph 5c of this ETL. The effect of wall friction is taken into account. The equations for the critical slip plane angle and the pressure coefficients are defined in paragraphs 6c and 6d.

2. Example 1 is taken from EM 1110-2-2502, Example 2, page M-5. Example 2 in this enclosure is the same as example 4 in Enclosure 2 with the addition of wall friction.

EXAMPLE 1

3. The earth pressures will be calculated for the soil geometry and properties given in the figure below. The earth pressure coefficients will be computed using pressure coefficients and compared against Coulomb's equation. The effects of wall friction will be taken into account in this example. Since the value of wall friction is affected by a number of factors, as described in paragraph 6a of this ETL, the value assigned to the wall friction was selected to demonstrate the mechanics of the procedure. Recommended values of wall friction will be addressed in subsequent engineering guidance.



4. Coulomb's equation (Equation 3-12 from EM 1110-2-2502) with $\theta = 90°$ reduces to

$$K_o = \frac{\cos^2 \phi_d \cos \delta}{\cos \delta \left[1 + \sqrt{\frac{\sin \phi_d \sin (\phi_d - \beta)}{\cos \delta \cos \beta}} \right]^2}$$

$$= \frac{\cos^2 21° \cos 10.5°}{\cos 10.5° \left[1 + \sqrt{\frac{\sin 21° \sin (21° - 14°)}{\cos 10.5° \cos 14°}} \right]^2}$$

$$= 0.05510$$

The horizontal effective earth force is computed as

$$P_{EE} = \frac{1}{2} K_o \gamma h^2 = \frac{1}{2} (0.5510)(0.12)(20)^2 = 13.224 \text{ kips/ft}$$

The vertical shear force is equal to

$$P_V = P_{EE} \tan \delta = 13.224 \tan 10.5° = 2.451 \text{ kips/ft}$$

5. The pressures and forces will now be computed using the simplified coefficient method. The critical slip plane angle is calculated using Equations 4 through 7 of this ETL as shown below.

$$A = \tan \phi_d + \tan \delta = \tan 21° + \tan 10.5° = 0.569203$$

$$c_1 = \frac{2 \tan \phi_d \, (\tan \phi_d + \tan \delta)}{A}$$

$$= \frac{2 \tan 21° \, (\tan 21° + \tan 10.5°)}{0.569203} = 0.767728$$

$$c_2 = \frac{\tan \phi_d \, [1 - \tan \phi_d \, (\tan ß + \tan \delta)] - \tan ß}{A}$$

$$= \frac{\tan 21° \, [1 - \tan 21° \, (\tan 14° + \tan 10.5°)] - \tan 14°}{0.569203}$$

$$= 0.122480$$

$$\alpha_{critical} = \tan^{-1} \left(\frac{C_1 + \sqrt{C_1 + 4C_2\,)}}{2} \right) = 42.092°$$

6. The pressure coefficients K and K_1 may now be calculated using Equations 9 and 10 of this ETL.

$$K = \frac{1 - \tan \phi_d \cot \alpha}{1 + \tan \phi_d \tan \alpha + \tan \delta \, (\tan \alpha - \tan \phi_d)}$$

$$= \frac{1 - \tan 21° \cot 42.092°}{1 + \tan 21° \tan 42.092° + \tan 10.5° \, (\tan 42.092° - \tan 21°)}$$

$$= 0.3985$$

$$K_1 = K \cdot \frac{\tan \alpha}{\tan \alpha - \tan \beta}$$

$$= \frac{0.3985 \tan 42.092°}{\tan 42.092° - \tan 14°}$$

$$= 0.5510$$

The horizontal effective earth force P_{EE} is calculated as

$$P_{EE} = \frac{1}{2} K_1 \gamma h^2 = \frac{1}{2} (0.5510)(0.12)(20)^2 = 13.224 \text{ kips/ft}$$

This agrees with the results obtained in paragraph 2.

7. The results will now be compared against the general wedge equation given in Equation 2 of this ETL.

$$W = \frac{\gamma h^2}{2(\tan \alpha - \tan \beta)} = \frac{0.12}{2(\tan 42.092° - \tan 14°)} = 36.7357 \text{ kips/ft}$$

$$P_{EE} = \frac{W(\tan \alpha - \tan \phi_d)}{1 + \tan \alpha \tan \phi_d + \tan \delta \; (\tan \alpha - \tan \phi_d)}$$

$$= \frac{36.7357(\tan 42.092° - \tan 21°)}{1 + \tan 42.092° \tan 21° + \tan 10.5° \; (\tan 42.092° - \tan 21°)}$$

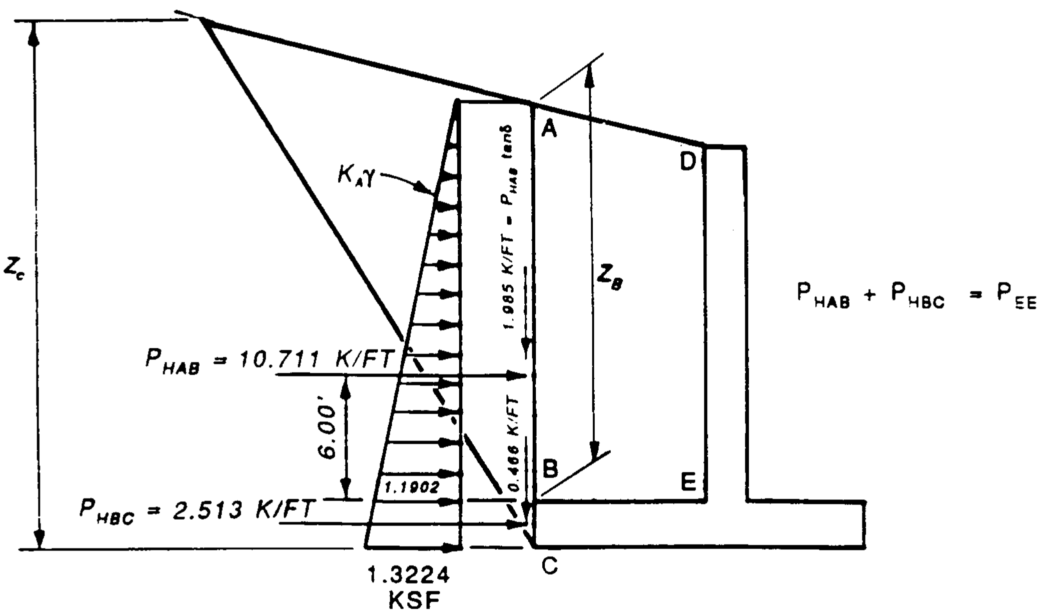
$$= 13.224 \text{ kips/ft}$$

This agrees with the previous solutions.

8. The lateral earth pressure distribution on the backfill may now be calculated. The pressures are calculated for two of the points shown on the following figure. The pressures can be calculated using the simplified method as follows:

$$p_{vC} = \gamma z_C = 0.12 \; (21.65) = 3.318 \text{ ksf}$$

$$p_{hC} = Kp_{vC} = 0.3985 \; (3.318) = 1.322 \text{ ksf}$$

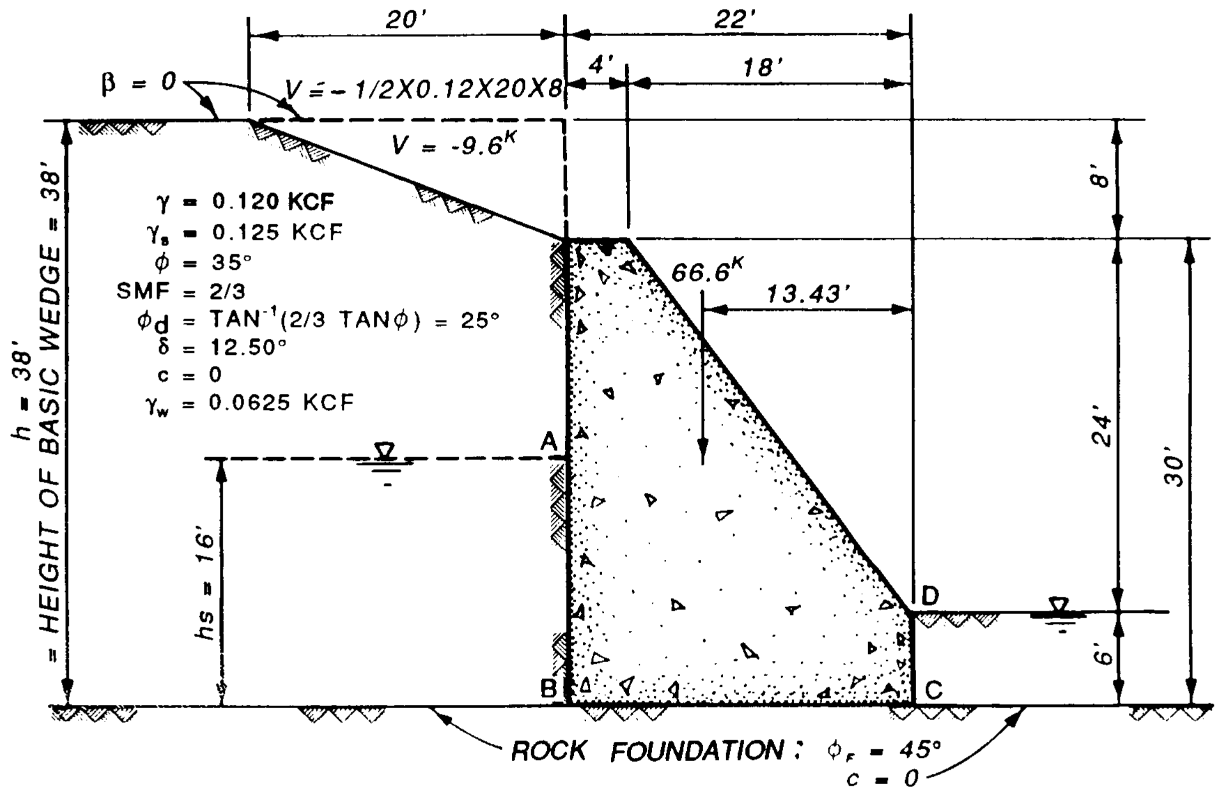


Since the pressure diagram is linear down to point C, the value for the pressure at point B may be calculated by proportions as follows:

$$p_{hB} = p_{hC} \frac{Z_B}{Z_C} = 1.322\ (18/20) = 1.190 \text{ ksf}$$

EXAMPLE 2

9. The earth pressures will be calculated for the soil geometry and properties given in the figure below. The earth pressures will be computed using the simplified coefficient method. The effects of wall friction will be taken into account in this example. Since the value of wall friction is affected by a number of factors, as described in paragraph 6a of this ETL, the value assigned to the wall friction was selected to demonstrate the mechanics of the procedure. Recommended values of wall friction will be addressed in subsequent engineering guidance.



10. The critical slip plane angle is calculated from Equations 4 through 7 of this ETL as shown below. Values for γ and V are taken from Example 4 in Enclosure 2.

$$A = \tan \phi_d + \tan \delta - \frac{2V(1 + \tan^2 \phi_d)}{\gamma h^2}$$

$$= \tan 25° + \tan 12.5° - \frac{2(-9.6)(1 + \tan^2 25°)}{0.1123(38)^2}$$

$$= 0.832149$$

$$c_1 = \frac{2 \tan \phi_d (\tan \phi_d + \tan \delta)}{A}$$

$$= \frac{2 \tan 25° (\tan 25° + \tan 12.5°)}{0.832149} = 0.771067$$

$$c_2 = \frac{\tan \phi_d (1 - \tan \phi_d \tan \delta)}{A}$$

$$= \frac{\tan 25° (1 - \tan 21° \tan 12.5°)}{0.832149}$$

$$= 0.502436$$

$$\alpha_{critical} = \tan^{-1}\left(\frac{C_1 + \sqrt{C_1 + 4C_2\ )}}{2}\right) = 50.016°$$

11. The pressure coefficient K may now be calculated using Equation 9 of this ETL.

$$K = \frac{1 - \tan \phi_d \cot \alpha}{1 + \tan \phi_d \tan \alpha + \tan \delta (\tan \alpha - \tan \phi_d)}$$

$$= \frac{1 - \tan 25° \cot 50.016°}{1 + \tan 25° \tan 50.016° + \tan 12.5° (\tan 50.016° - \tan 25°)}$$

$$= 0.35465$$

12. The lateral earth pressure distribution may now be calculated. The pressures are calculated for the points shown on the figure on the following page. The pressures are calculated as follows:

p_{v1} = 0.12(21.067) = 2.5280 ksf

p_{v2} = 0.12(22) + 0.0767(1.849) = 2.7818 ksf

p_{v3} = 0.12(22) + 0.0767(16) = 3.8672 ksf

p_{h1} = Kp_{v1} = 0.35465(2.5280) = 0.8966 ksf

p_{h2} = Kp_{v2} = 0.35465(2.7818) = 0.9866 ksf

p_{h3} = Kp_{v3} = 0.35465(3.8672) = 1.3715 ksf

The vertical shear force is calculated as

$P_V = P_{EE} \tan \delta$ = 24.702 tan 12.5° = 5.476 kips